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FORT KNOX, KENTUCKY

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2 December 1952

THE STEREOPTOMETER - AN INSTRUMENT FOR THE STUDY OF BINOCULAR VISION

*Subproject under AMRL Project No. 6-95-20-001, Subtask, Relationship Between Optical Aids and Perception in Visual Observation.

MEDICAL RESEARCH AND DEVELOPMENT BOARD
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THE STEREOPTOMETER - AN INSTRUMENT FOR THE STUDY OF BINOCULAR VISION

by

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ABSTRACT

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OBJECT

The stereoptometer was developed to incorporate the psychovisual task of the stereoscopic range finder into a device amenable to laboratory manipulation. Such an instrument was desired for use in the study of factors in the individual, the range finder, and the target field which affect stereoscopic range finder performance.

RESULTS

A preliminary model of the stereoptometer provided asymmetrical convergence of the right element only and a sensitivity of 20 seconds of arc per division. The current instrument provides a choice of symmetrical or asymmetrical left or right convergence and gives a sensitivity of 4 seconds of arc per division.

RECOMMENDATIONS

It is recommended that the possibilities of the stereoptometer as a selection device and/or trainer for stereoscopic range finder operators be investigated.

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THE STEREOPTOMETER - AN INSTRUMENT FOR THE STUDY OF BINOCULAR VISION

I. INTRODUCTION

The stereoptometer was developed to incorporate the psycho-visual task of the stereoscopic range finder into a device amenable to laboratory manipulation. Such an instrument was desired for use in the study of factors in the individual, the range finder, and the target field which affect stereoscopic range finder performance.

The instrument is, in principle, a stereoscopic range finder (2, p. 254) of unit base and unit magnification, or a Haploscope (4) in which the adjustment for accommodation has been sacrificed in the interest of mechanical simplicity and precision of vergence measurement. A reflex sight (2, p. 241) is utilized to project into the field of view of each eye of an observer a star point or other reticle, without interposing optical aid other than spectacles, if required, between the observer and his field of view. The projected reticle images may be fused to constitute a test object manipulable in depth by the adjustment of the angle of vergence between the parallel beams of light used to project the reticles.

II. ELEMENTS OF THE INSTRUMENT

The major elements of the stereoptometer are shown in Figure 1. The reflex sights, the right bearing and arm assembly and the dial gauge with its slide-bearing mount are plainly visible. In the photograph, the left arm is pinned by a large knurl-headed taper pin to establish asymmetrical right vergence.

The functioning of the instrument is primarily dependent upon control of the interrelation of the reflex sights before the two eyes. To establish this control, a three-part mechanical system is employed which serves to support, rotate, and measure the angle of vergence between the sights. A review of the characteristics of the reflex sight will help to delineate what is required of the mechanical system.

A. The Reflex Sight

The reflex sight (Fig. 2) is essentially a collimator with a reflection plate to permit indirect viewing. It consists, in principle, of a light source, a reticle, a lens, and a reflection plate. The net result is to produce a parallel beam of light carrying the image of the reticle. When this beam is observed by an eye looking into the reflection plate, the image of the reticle is localized at an indefinite distance in front of the observer.

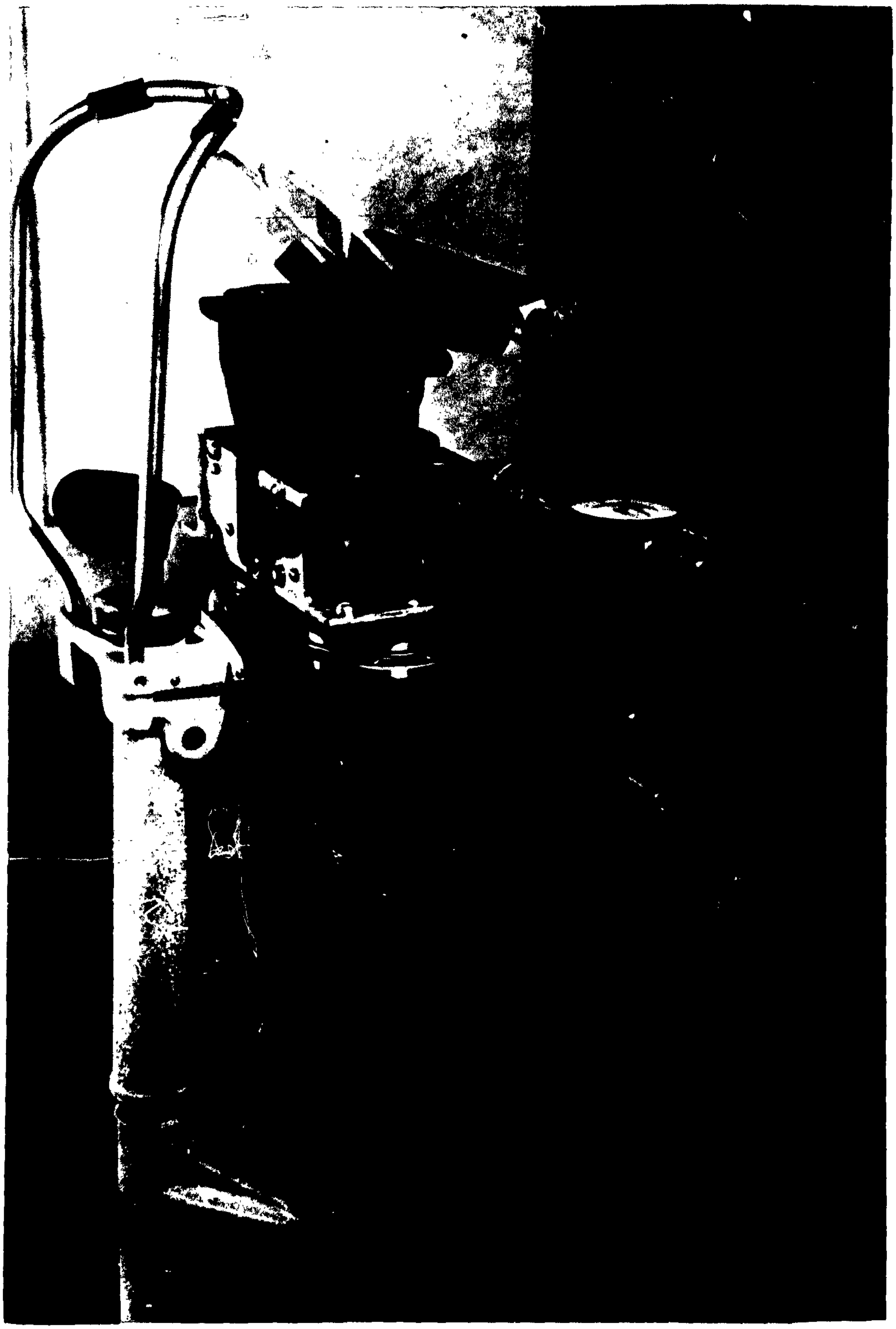

FIG. 1 THE STEREOPTOMETER

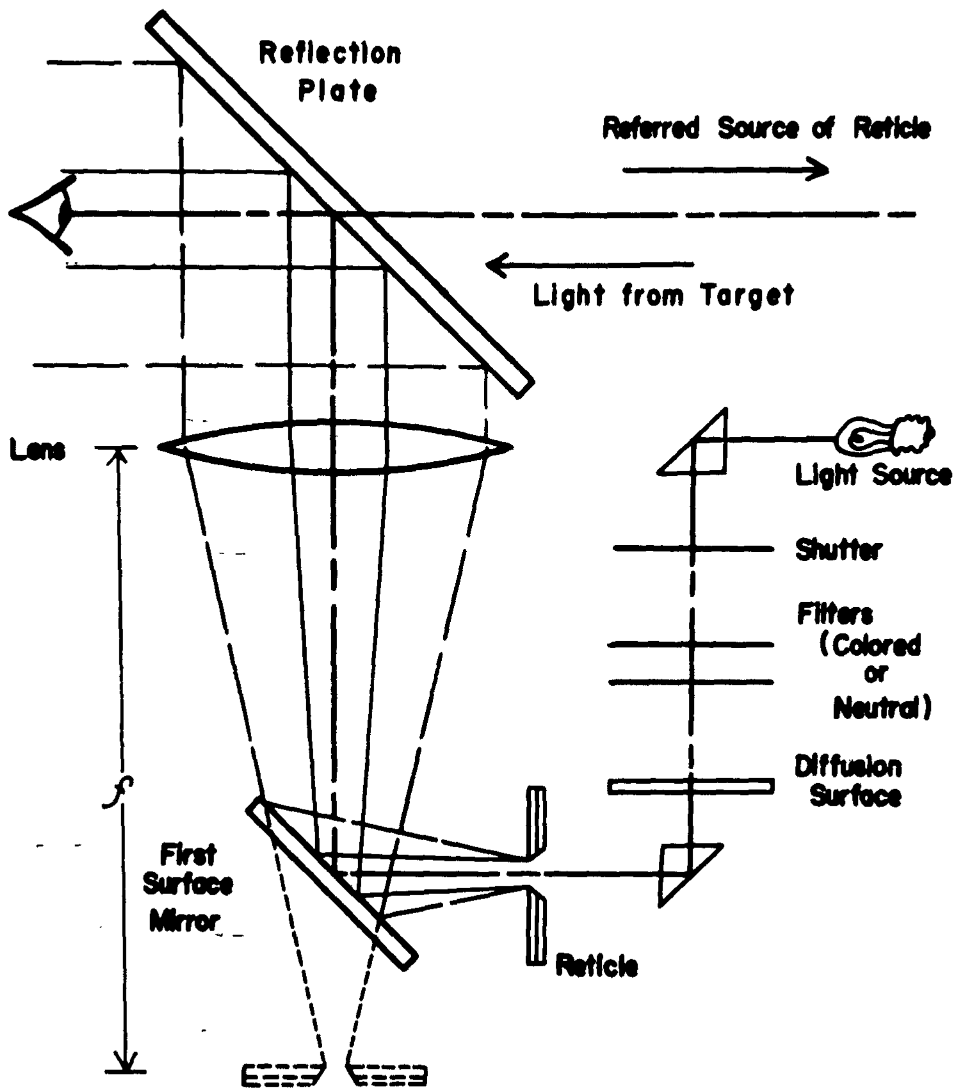

FIG. 2 SCHEMATIC DIAGRAM OF A REFLEX SIGHT

The reflex sight may take many forms, depending upon the optical precision required and the proposed employment. In a preliminary model (1) of the stereoptometer, a reflex sight utilizing a Mangin mirror was used. In the current instrument, an optical system such as diagrammed in Figure 2 is employed.

Characteristic of images carried by parallel beams, the reticle projected by the reflex sight is localized in the line of sight of the observing eye. Lateral displacement of the observing eye results in a like displacement of the reticle image. Lateral rotation of the observing eye results in a contrary displacement of the reticle image. The first of these characteristics of parallel beams makes unnecessary any adjustment for interpupillary distance when two beams of sufficient width are used. The second makes possible the act of ranging. Also, measurement of the vergence angle of the eyes in setting the simulated test object by the angle of vergence of the parallel beams is possible even though the axes of rotation of the reflex sights do not coincide with those of the eyes since parallel lines form equal angles with transverse parallels.

B. The Mechanical System

The mechanical system of the instrument may be considered in three parts. Each was designed to be independent of the other in function for simplicity of construction and to avoid interaction in operation. These parts are the bearing and arm assembly, the drive-screw assembly, and the dial gauge and slide-bearing assembly. These three parts of the mechanical system are necessary whether one or both of the reflex sights are verged.

The bearing and arm assembly provides a stable and rotatable mount for the reflex sights as well as a rigid arm through which to apply the rotational force and from which to measure the angle of vergence. In the current instrument, two of these assemblies are used, one for the reflex sight before each eye. The basic element of the assembly is a three inch, precision ground, ball, thrust bearing.

The drive-screw assembly (Fig. 3) provides the force, acting against a spring, to diverge the bearing and arm assemblies. The drive screw is set between the arms, and is of dual pitch in a 2:1 ratio. The dual pitch screw was selected rather than the more conventional left and right thread since it permits the use of a split nut (A) as a reference point for symmetrical convergence. This makes possible adjustment to eliminate play or slap which would show up as lateral weave of the test object when the direction of movement is reversed. The dual pitch screw also permits two additional reference points (B) for movement to provide a choice of either asymmetrical right or asymmetrical left vergence. The resultant change in angle between the reflex sights with knob rotation is the same in all three conditions.

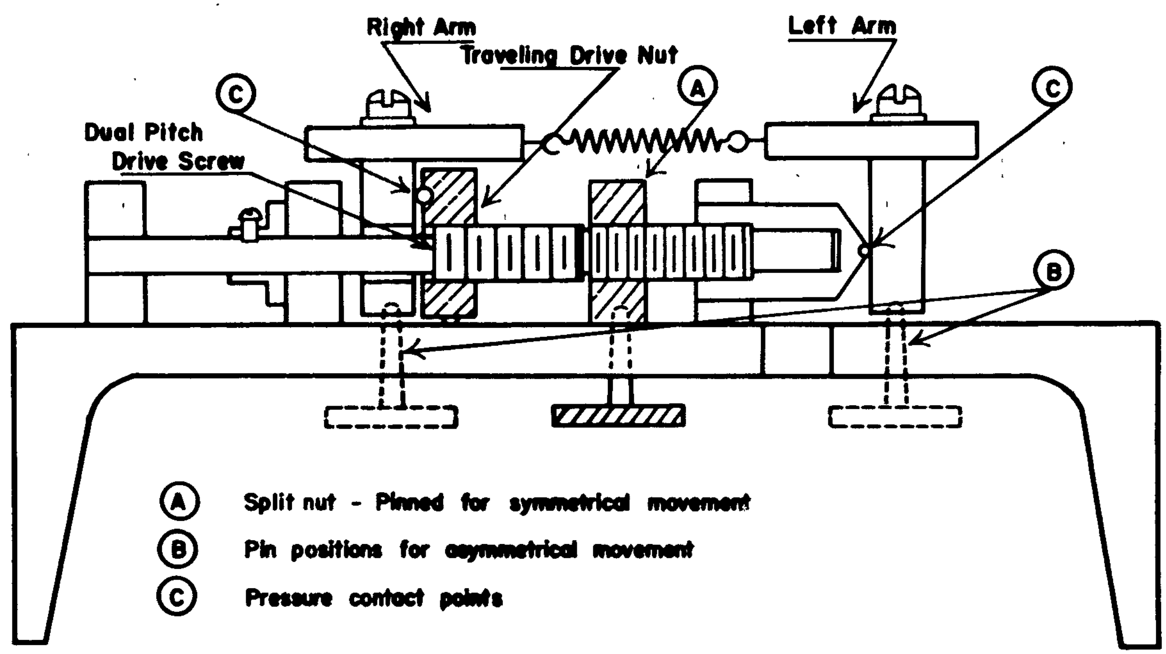

FIG. 3 SCHEMATIC DRAWING OF DRIVE SCREW ASSEMBLY
Thread Ratio - 2:1

Independence of the screw assembly from the arm and bearing assemblies is obtained through the use of pressure contact points (C) where the screw assembly meets the arms.

The dial gauge and its slide-bearing mount is also located between the arms. The dial gauge is so mounted as to permit the use of a single gauge to record the movement of either or both arms, and to give direct readings for all conditions of vergence. This placement of the dial gauge requires that the combined length of the body and plunger of the gauge and the distance between the pivots of the arms be approximately equal and the combined dial gauge length longer than the distance between the arms by a length equivalent to the tangent of two to four degrees. This requirement must be met in order that the instrument may be adjusted to read linearly.

The dial gauge used in this instrument can be read directly to one ten-thousandth of an inch and permits two-tenths of an inch of plunger movement. With this gauge place a little over five inches from the pivots of the arms, sensitivity is approximately four seconds of arc per division. To permit measurement of ranges from infinity in to one meter, an angular distance of approximately four degrees, the dial gauge is used through its linear range twice.

III. CALIBRATION

The measuring triangle of the instrument associated with each arm is calibrated separately. The axis of movement of the slide-bearing mount establishes the short side of one of the measuring triangles while the axis of movement of the plunger of the dial gauge establishes the short side of the other measuring triangle. The hypotenuses of the triangles are established by the contact points of the dial gauge with the arms, the body in one case and the plunger in the other, and the pivot points of the respective arms. The long side of the measuring triangles of the instrument are not physically identifiable. The determination of their length is the object of the calibration procedure. These lengths when determined are used in conjunction with the observer's interpupillary distance to convert dial gauge values to ranged distances.

Calibration was accomplished by the use of mirrors mounted in place of the reflex sights on the bearing and arm assemblies and collimated light beam bearing a reference edge. Calibration triangles were arranged symmetrically about parallels from the pivot points of the arms perpendicular to the facing wall on which was mounted a calibrated grid. Changes in the acute angle of the measuring triangles of the instrument were observed on this calibrated grid with the aid of the collimated light beam projected over a distance of twenty-five feet. Four degrees of arc served in the calibration triangles for a two-degree movement in the instrument triangle. Movement of the reflected beam was read to a tenth of a millimeter in the calibration triangles.

One consideration in the calibration which required a trial and error adjustment was the positioning of the dial gauge between the arms. Since it is desired to measure convergence angles as great as four degrees, and since the tangent function is linear to five places for only two and a half degrees, it is necessary that the instrument triangles be balanced about their perpendiculars so that approximately two degrees are measured negatively and two degrees positively. The adjustment is critical only for that arm with which the body of the dial gauge moves as the measuring element. For the other arm, where the plunger of the dial gauge is employed as the measuring element, a two degree sweep in the instrument triangle is used twice over to cover the four degrees.

Alignment of the reticle images projected by the reflex sights with respect to each other is accomplished with the aid of a Keuffel and Esser double collimator.

IV. TEST OBJECT CUES AVAILABLE TO THE OBSERVER

The depth cues available to the observer from the test object would seem to be only the proprioceptive cues of the binocular vergence, double images, and disparity between the images in the two eyes. Yet, certain additional factors are present which may be significant in the perception of the depth placement of the test object. The most obvious of these is a contradictory cue of test object size. The apparent relative size of the test object grows larger with increasing distance contrary to the behavior of a real object. This is a fundamental property of reticles. It arises from the fact that the reticle subtends a constant visual angle while the receding target subtends an ever smaller visual angle. Concomitant to this is the linear size relation of the test object to the reference object. If both objects are of the same shape, the assumption of linear perspective may operate to produce errors of localization. Lastly, the relative brightness of the test object with respect both to the background on which it is projected and the target may significantly influence the setting of the test object.

V. POSSIBILITIES OF EMPLOYMENT

The data obtained from the stereoptometer provide two measures; 1) a spatial localization measure, the mean range reading, and 2) a stereoptic acuity measure, the variability of the range readings. The appropriate expression of these measures will depend upon whether the instrument is observer or experimenter operated, and whether the data are transformed from angular measure to linear measure. Consistent with the approach used, the observer's task may be to place the test object at the same distance from himself as the reference object; or to make judgments of the relative depth position of the test object with respect to the reference object, as the experimenter adjusts the instrument and exposes the test object for timed intervals.

The variables that may be studied in the target field are limited only by the experimenter's ingenuity in manipulation of the environment. With reticle brightness control and a selection of neutral density filters for the reflection plate, the test object may be projected by the observer into almost any field of view which one would care to consider. The instrument has been used to investigate the depth dimension of real terrain under field conditions, reduced stimuli and illusion situations in the laboratory, and simulated scenes projected from stereoscopic slides.

The specific instrument described here was constructed to study symmetrical, asymmetrical right, and asymmetrical left vergence. Modification will permit study of other instrument factors to include magnification (optical and base) and verging elements (target or reticle).

The condition of symmetrical vergence offers a unique test of binocular vision. A report by the observer of left or right movement in the test object is referable to suppression of vision in a specific eye, a report of radial movement is referable to binocular vision. Fusion limits may be explored through the report of doubling of the test object image. Modification of the reticle mounts to permit manipulation and the utilization of configurations as reported by Ogle (3) would permit study of fixation disparity and aniseikonia.

VI. RECOMMENDATIONS

It is recommended that the possibilities of the stereoptometer as a selection device and/or trainer for stereoscopic range finder operators be investigated.

VII. BIBLIOGRAPHY

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